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*Atmospheric Infrared Sounder*

# **Changes to Level 1 Software for V6 – Part 2 (Technical)**

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# AIRS Spectral Calibration Primer

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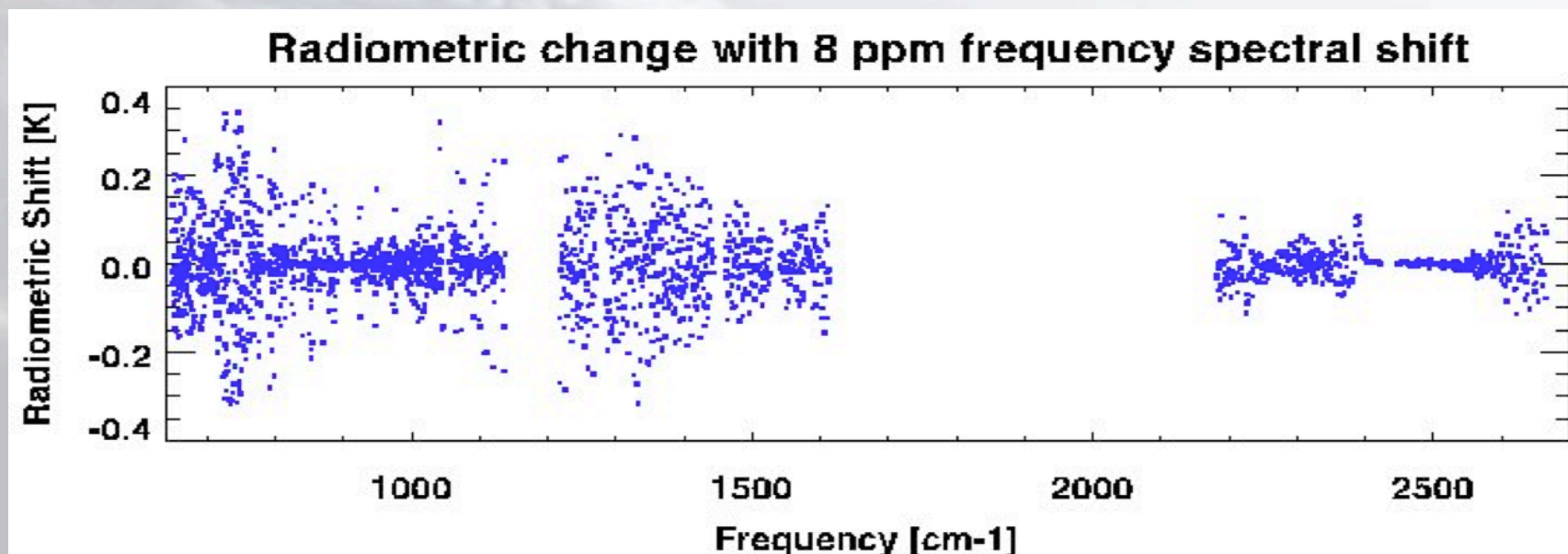
- **AIRS measures radiance at 2378 frequencies with 2378 physical detectors, each 50  $\mu\text{m}$  wide.**
- **A combination of optics places a distinct frequency range on each detector.**
- **The frequency of each detector is extremely stable, varying less than 2% of frequency spacing over the mission to date.**
  - ***For all weather uses and most climate uses the frequencies can be treated as constant***
  - ***For some climate purposes such as long-term trends it is useful to know the frequencies more precisely***



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# The Challenge of Spectral Calibration

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- Any error in knowledge of SRF position will manifest as an error in observed brightness temperature
- AIRS SRF knowledge requirement is 8 ppm in frequency



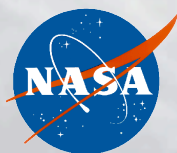
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## A Case Where Spectral Shifts Matter

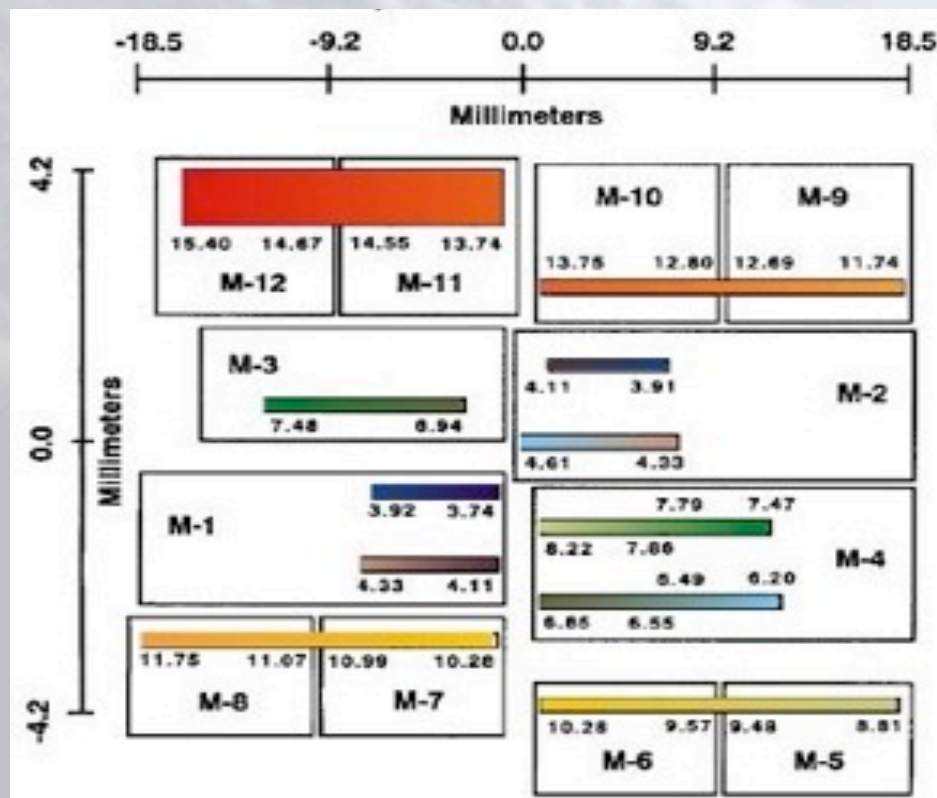
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- **Consider the case where we are comparing AIRS & IASI data at  $712.25 \text{ cm}^{-1}$** 
  - ***This frequency sounds the atmosphere at ~400 hPa***
    - Typical temperatures are ~250 K for tropical cases
  - ***Day/Night difference at 400 hPa is a proxy for convection***
    - Can indicate climate change
  - ***IASI data shows 9:30 AM – 9:30 PM = 180 mK***
  - ***AIRS data shows 1:30 PM – 1:30 AM = 240 mK***
  - ***Difference is 60 mK***
  - ***Corresponds to 3 ppm frequency shift***
  - ***Need to reduce uncertainty to 10 mK  $\Rightarrow$  0.5 ppm***



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Direction of effective  
focal plane motion

## AIRS Focal Plane

### Note on units:

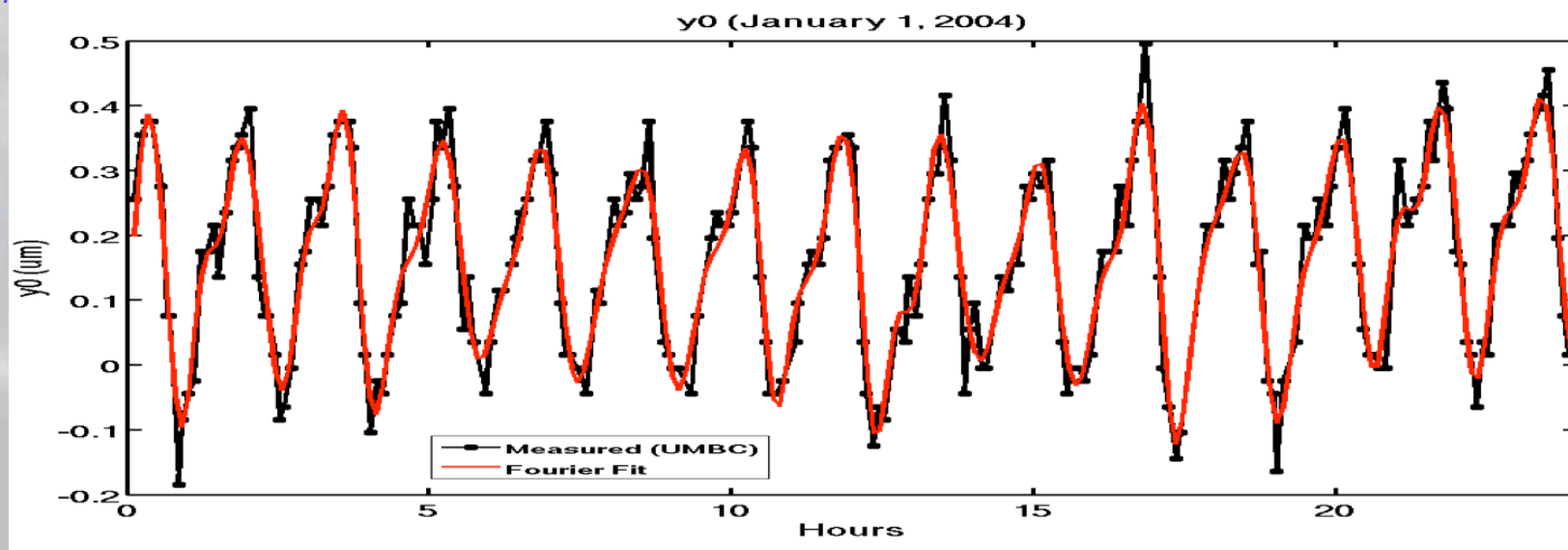
- 1  $\mu\text{m}$  in focal plane dimensions is:
  - 2% of channel spacing
  - $\sim 20 \text{ cm}^{-1}$  @  $1000 \text{ cm}^{-1}$
  - $\sim 8.4 \text{ ppmf}$
  - 0.02  $\mu\text{m}$  wavelength at 10  $\mu\text{m}$  wavelength
- 0.1  $\mu\text{m}$  in focal plane dimensions is:
  - 0.2% of channel spacing
  - $\sim 2 \text{ cm}^{-1}$  @  $1000 \text{ cm}^{-1}$
  - $\sim 0.84 \text{ ppmf}$
  - 0.002  $\mu\text{m}$  wavelength at 10  $\mu\text{m}$  wavelength



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## One Day of AIRS Spectral Data

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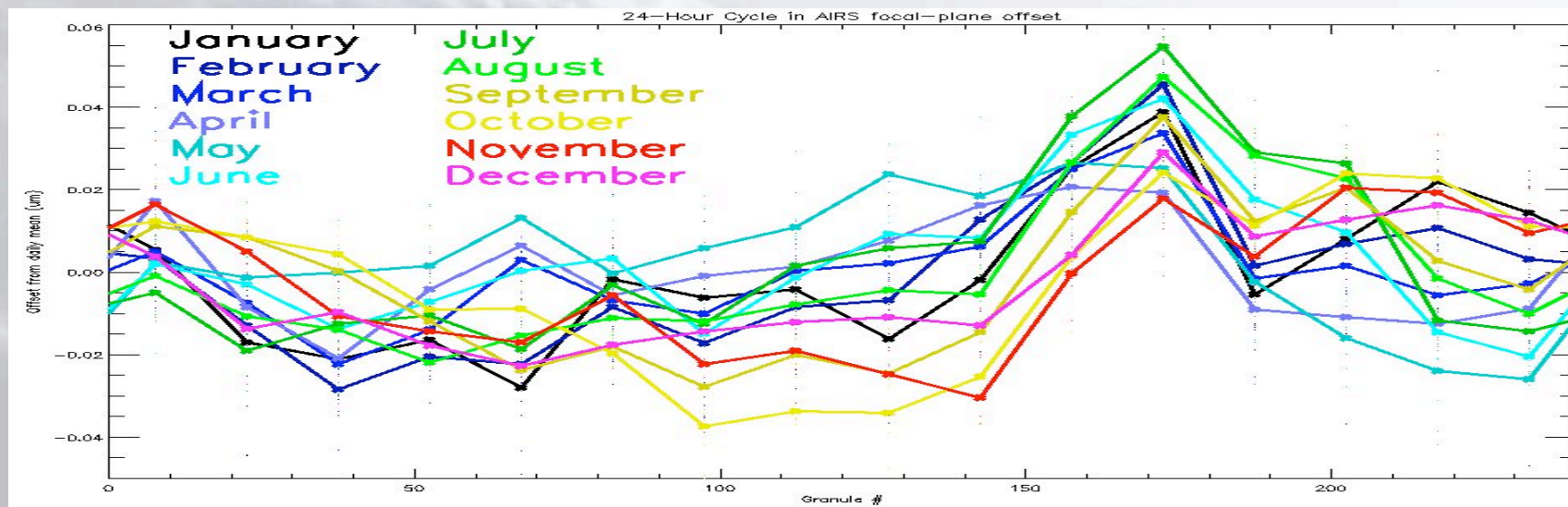
- **Orbital modulation of the AIRS focal plane position for one day of data.**
  - *A  $y_0$  is shown for every 6 minutes of data.*
  - *The red smooth line is the focal plane offset after noise filtering.*
- **Peak-to-peak orbital cycle is  $\sim 0.5 \mu\text{m}$  or  $\sim 4 \text{ ppm}$ .**



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## 24-hour modulation

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- 24-hour modulation of the AIRS focal plane position for one day of data.
- There is a peak near T17Z (granule 170) for all seasons
  - *This is when exposure to the coldest part of Antarctica is greatest*
- Peak-to-peak daily cycle is just  $\sim 0.05 \mu\text{m}$  or  $\sim 0.4 \text{ ppm}$ .

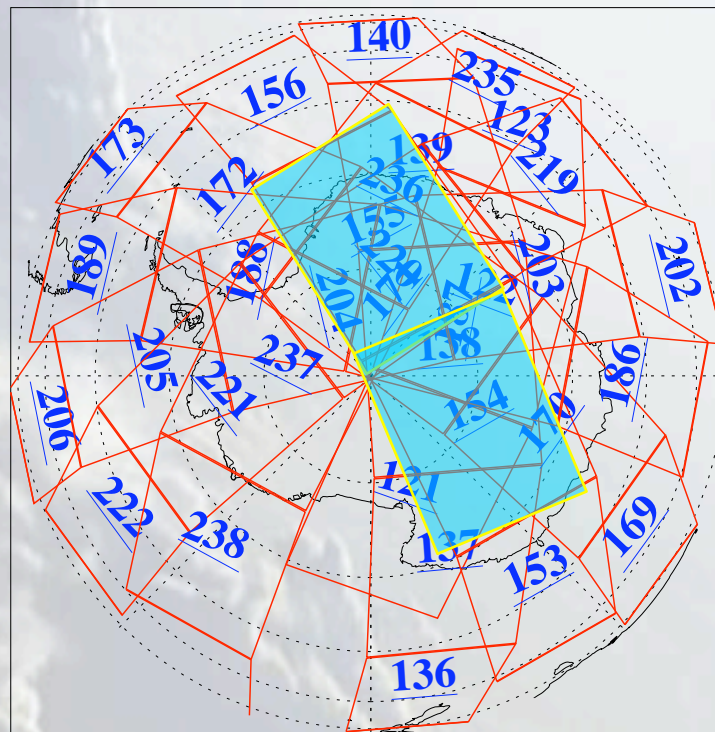
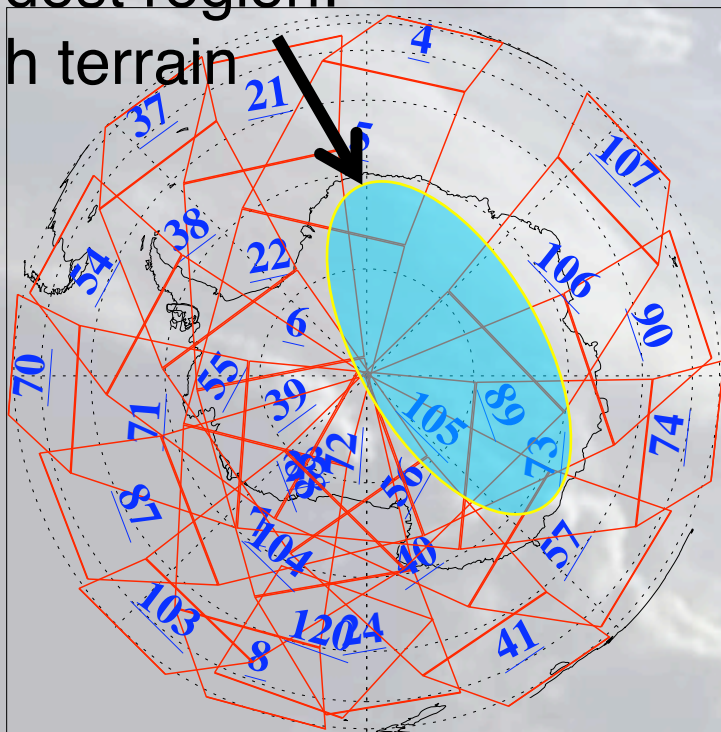


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## Explaining the 24-hour cycle

Coldest region:  
High terrain



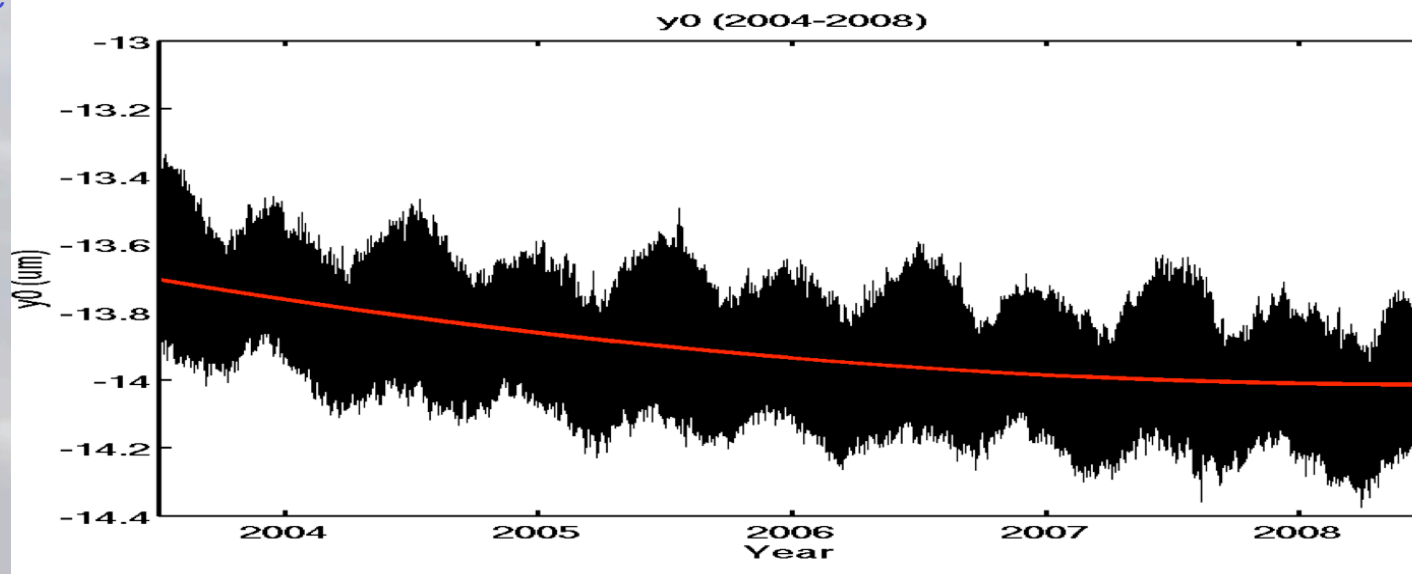
The coldest part of Antarctica is on one side. Around T16Z each day Aqua has tracks with maximum overlap with this region.



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## AIRS Spectral Shifts: Mission to Date

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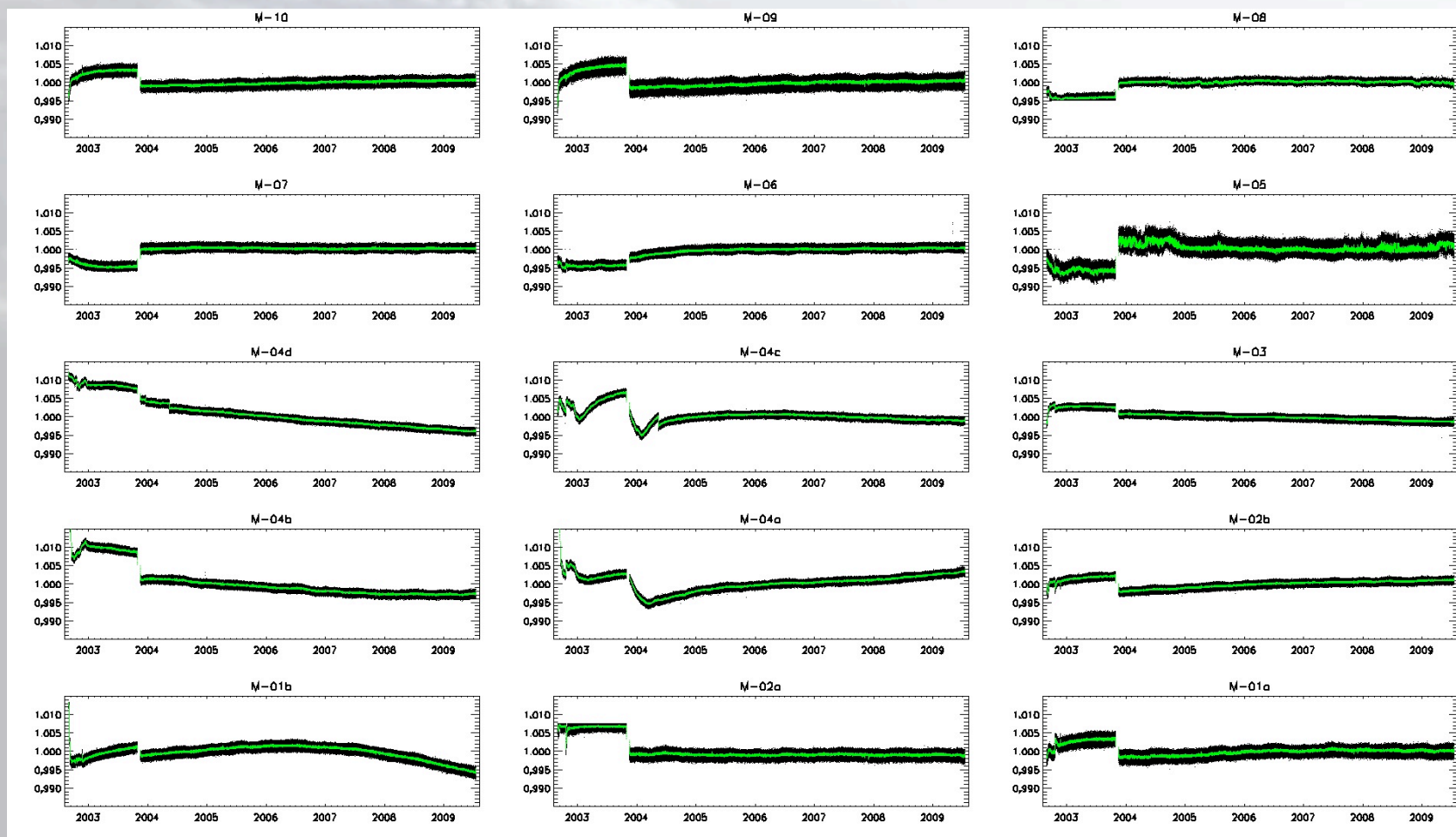
- Changes in 5 years of AIRS data in terms of  $y_0$  as a function of time.
- The red line shows the long-term component:
  - An annual trend of  $-0.07 \mu\text{m}$  per year early in the mission
  - Leveling off around 2008.
- Worst case peak-to-peak orbital cycle + 24-hour + seasonal + long term is  $\sim 1 \mu\text{m}$  or  $\sim 8$  ppm.



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# Breaking news: long-term change differs by module





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# Living with Spectral Shifts

## Approach #1: Ignore it!

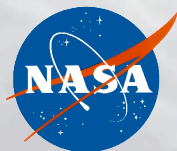
- Easiest
- Good enough for most uses

## Approach #2: Diagnose and analyze appropriately

- Tables will be available with the correct instantaneous frequency
- Users can employ this knowledge in their analyses

## Approach #3: Change the product to compensate for shifts

- New AIRS Level-1C products will contain radiances with the effects of frequency shifting removed.

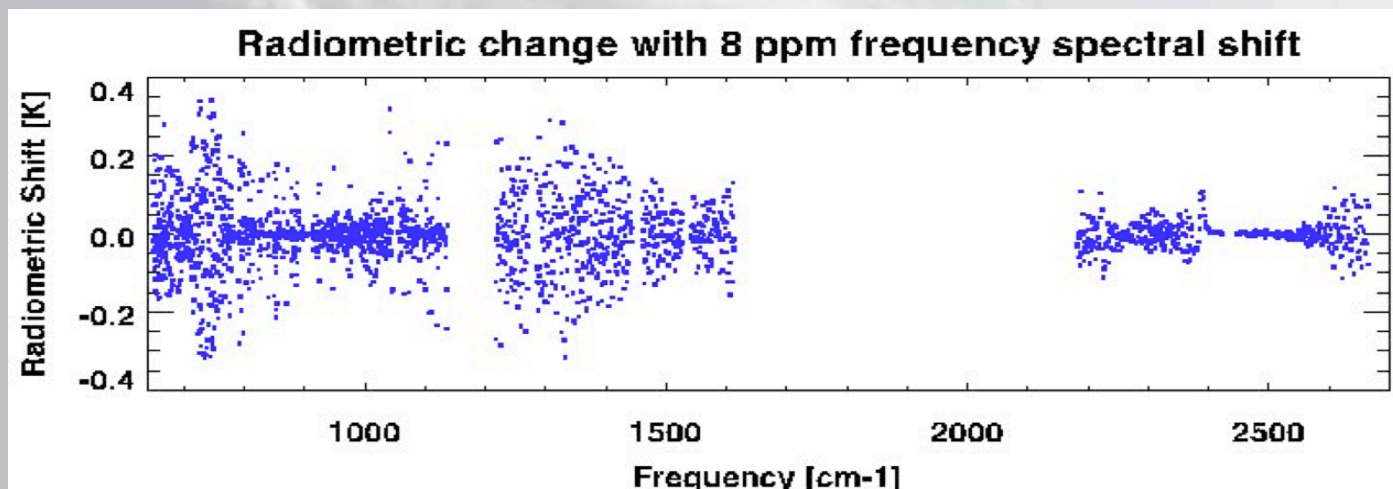


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## Option 1: Ignoring spectral shifts

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- All AIRS uses to date have neglected spectral shifting.
- This remains a reasonable option.
  - *Definitely best for weather applications*
  - *Correct for all but a few specific climate applications*
- The worst case peak-to-peak orbital cycle + 24-hour + seasonal + long term is  $\sim 1 \mu\text{m}$  or  $\sim 8 \text{ ppm}$ .
  - $< 0.4 \text{ K}$  even for channels on steepest slopes
  - $< 0.1 \text{ K}$  for almost all channels





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## Option 2: Compensate for shifts

- We'll soon release a simple look-up giving shifts and frequencies for any time
- Use a variable-frequency forward model
  - *This is what AIRS Level-2 will do in version 6 using UMBC's SARTA*
- For some simpler analyses a simple first-order correction can be used
  - *Example: comparing tropical day vs. night temperature at 400 hPa using 712.25 cm<sup>-1</sup> channel*
  - *Look-up table gives day vs. night tropical frequency shift*
  - *Apply rough spectral slope  $dT/d\nu$  to get first-order correction*



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## Option 3: Use Level-1C

- **Where Level-1B reports what the instrument did observe, converted to physical units, Level-1C reports what an ideal instrument would have seen**
- **In Level-1C the known shifts are used to adjust the radiances to what would have been seen if there were no spectral shift.**
  - *Channels in need of replacement are determined*
  - *Gaps are filled.*
  - *Radiances are shifted (BT domain, cubic spline per module)*
  - *Other radiometric adjustments are applied*



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## Option 3: Use Level-1C

- **Using Level-1C will be as easy as Option 1**
  - *Level-1C format is identical to Level-1B*
- **Level-1C will be available from GES DISC like Level-1B**
- **If you already have Level-1B, we'll provide a program to convert it to Level-1C on the fly.**
- **Inside Level-2 the Level-1C library may be used to convert radiances on the fly for use in regressions**



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## Conclusions

- **AIRS Level-1B Version 5 (previous version) calibration was already accurate enough for weather and many but not all climate applications.**
- **AIRS Version 6 Level-1C will cut down the RMS error from spectral shifting from ~45 mK to ~4.5 mK**
  - ***This will unambiguously qualify AIRS Version 6 Level-1C as a climate-quality product.***